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Spread of Direct Seeded Lowland Rice in Northeast Thailand: Farmers' Adaptation to Economic Growth

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Abstract

The accelerated economic growth of Thailand since the late 1980s has made the urban-rural relationship more direct in terms of people's mobility and the circulation of information and money, and this is transforming landuse and agriculture. A typical example of this transformation is the change in the planting method of lowland rice in Northeast Thailand, which the present study highlights. Two years' field observation of 178 plots and interviews with 100 farmers in the Chi and Mun river basins demonstrated a drastic change in the planting method from transplanting to dry seeding as a result of trial and error by farmers. Northeastern farmers tend to attach greater importance to minimizing labor input to rice cultivation than to maximizing rice production. This change reflects the structural changes in the region: the rise to prevalence of the money-based economy and the disappearance of the rice-based economy.

I Introduction

Before the 1970s, almost all rice cultivation in Northeast Thailand was rainfed and yielded 1 to 2 t/ha of unhusked rice by the transplanting method. The produce was mostly consumed by the farmers and the surplus in a good harvest year, if any, was stored to prepare for poor harvests in subsequent years [Fukui 1993 : 296-299].

During the 1970s and 1980s, rice cultivation was "modernized." Power-tillers were introduced, which reduced water requirement for land preparation and enabled timely land preparation and transplanting. Chemical fertilizer application also started during the 1970s, which doubled rice yields in some areas and prompted farmers there to start commercial cultivation of rice. A government agency constructed large-scale irrigation systems, which enabled intensification of rice cultivation from single-cropping to double-cropping. A number of small-scale pumping irrigation systems were constructed along the Chi and Mun rivers, which stabilized rice production in the rainy season and allowed dry-season cultivation of rice or vegetables. The modernization during the 1970s and 1980s, therefore, aimed at increasing agricultural production and income from the agricultural

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sector in order to catch up with economic growth in the rest of the country, and it was partly successful.

However, accelerated economic growth since the late 1980s, or, more clearly in rural areas, since the early 1990s, is making the urban-rural relationship more direct in terms of people's mobility and the circulation of information and money. Its impacts have become apparent in landuse and agriculture as well as village life in the Northeast. Three types of change are noted.

First, labor-saving techniques have become widespread. Increasing job opportunity in the industrial and service sectors in Bangkok and its suburbs attracts numerous farmers away from their villages seasonally as well as permanently [Nakada 1995: 537-541]. This causes shortage of agricultural labor both in the family and for hire, raises wages for agricultural labor and promotes further farm mechanization. It also brings changes in cultivation techniques and landuse. Replacement of cassava with eucalyptus is an example of the latter.

Second, intensive and highly profitable ventures, such as fruit and vegetable cultivation, seed production, aquaculture and animal husbandry are spreading to meet the demands of expanding domestic and overseas markets [see Kono and Saha 1995]. In most cases, these enterprises are carried out by people of Chinese origin or supported by private companies. With the capital and the capability to upgrade farm conditions and develop new technology, these groups are expected to be a driving force behind the agricultural sector's response to new demands by consumers. Simultaneously, their landuse and agriculture may cause environmental pollution, particularly through overuse of chemicals, because the economic incentive is likely to override concerns for environmental conservation.

Third, reactions are emerging against the changes in landuse and agriculture induced by economic growth. Increased use of chemicals has produced a backlash of ideas concerning natural farming and organic farming. Expansion of agricultural land and the consequent depletion of forest resources have aroused greater concern about the preservation of community forest, as a result of which its area has expanded in places [Kono *et al.* 1994]. Although these reactions have yet to influence actual landuse and agriculture, they may provide a key to harmonize the changes with environmental conservation and to mitigate social conflicts induced by the changes.

Lowland rice cultivation in Northeast Thailand is not an exception. It has been undergoing transformation in response to the changes in the urban-rural relationship since the late 1980s, even though most of it remains under rainfed, which might restrict the adoption of potential technological innovations [Fukui 1993: 308-309]. A typical example of this transformation is a change in the planting method, from transplanting to direct seeding. This paper describes the process of this change and discusses its implications. Special attention is paid to the hydrological environment of lowland rice cultivation, which is closely related with the change in planting method.

II Hydrological Environment of Lowland Rice

Paddy land is distributed through most of the Northeast. In some areas, it is found side by side with upland, forming a mosaic that reflects the microrelief. Elsewhere, it forms an extensive, flat, monotonous landscape. Fukui [1994] called the latter the "core areas," not only because they are most productive but also because they played an important role in the making of the Northeast in general. The most extensive core areas are the lowlands along the Mun River between Nakhon Ratchasima and Sri Sa Ket, and along the Chi River between Khon Kaen and Roi Et. These two core areas were chosen for the present study.

Ten cross sections, five each across the Chi (C1~C5) and Mun (M1~M5) Rivers, connecting provincial or district towns on both sides of the rivers were selected (Fig. 1), and 178 plots in total were selected along them for observation of water conditions, crop growth and cultivation techniques during the rainy season in 1994 and 1995 (see Appendices). Moreover, 100 farmers, who occupy 107 survey plots, were interviewed on their farming.

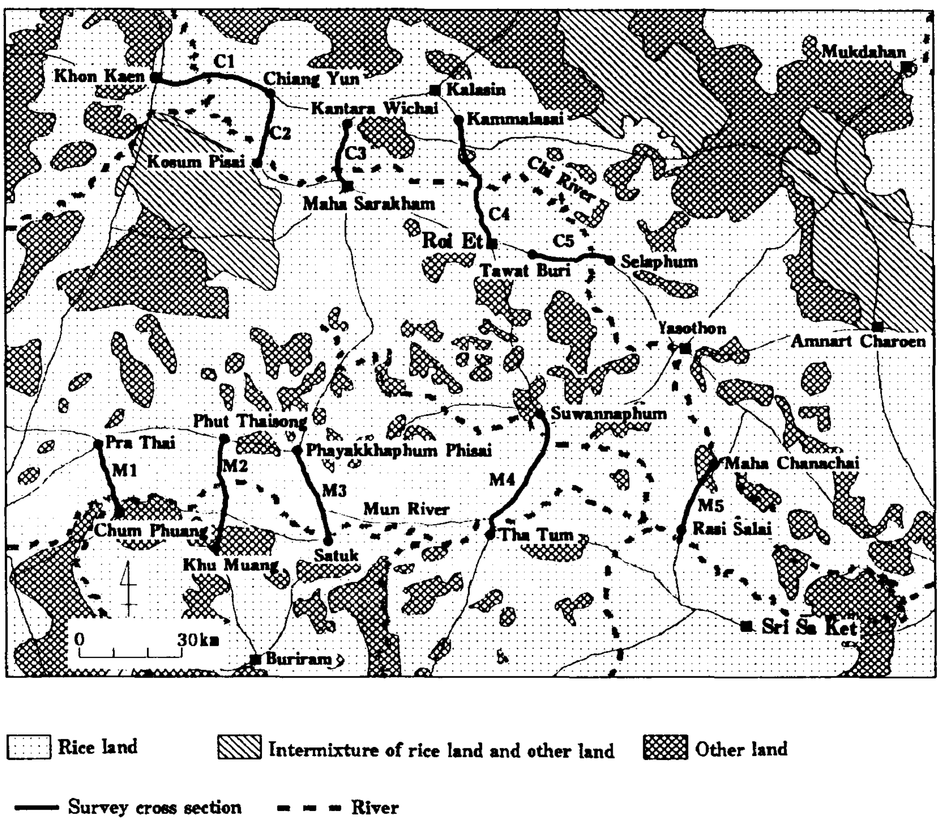

Fig.1 Location of Survey Cross Sections

Note: Based on North-eastern Land Use Map of Thailand (1990) of scale 1 : 500,000

Of the 178 survey plots, 32 are irrigated and 146 rainfed. The former are either in the Nam Phong-Nong Wai system (16 plots along C1 and C2 sections), the Lam Pao system (6 plots along C3 section) or small-scale pump irrigation systems (10 plots along C3, C4, M2 and M3 sections). The Nam Phong-Nong Wai, Lam Pao and small-scale pump irrigation systems started functioning in the early 1970s, late 1960s, and 1980s and early 1990s, respectively. "Rainfed" does not mean total lack of water control; water is controlled at the farm level, e.g., by pumping from one plot to another or utilization of a road-side temporary water body.

The survey revealed a wide variation in water conditions of rainfed lands according to rainfall, toposequence, and soil. In general, annual rainfall increases eastward in the study area, from 1,100 mm in the west to 1,500 mm in the east. Paddy fields located lower in the toposequence enjoy run-off from the catchment area and have heavier soils with greater soil moisture-holding capacity and lower percolation. Precise evaluation of the hydrological environment considering these numerous factors requires measurements and observations over a long period [Fukui 1993 : 193-222] . In the present study, rainfed paddy fields were categorized into three types from the viewpoint of hydrological characteristics.

(A) Most vulnerable to drought: this type of paddy field is located in the higher positions in the toposequence and has sandy soil and almost no chatchment. Dry Dipterocarpus trees such as *sabaeng* (*Dipterocarpus intricatus*) and *saat* (*Shorea spp.*) remain in the fields. In most cases, rice cultivation there frequently suffers from drought, and stable rice production cannot be expected. Fourty-five survey plots were identified as belonging to this type.

(B) Less vulnerable to both drought and flood: soil and topographic conditions of this type are in between type (A) and (C). Tall mixed deciduous trees such as *kra thum* (*Anthocephalus cadamba*) and *khae* (*Dolichan drone spp.*) can be observed. Comparatively stable production can be expected. Ninety-three plots were identified as belonging to this type.

(C) Most vulnerable to flood: this type of paddy field is located along rivers and streams, where the land was originally covered with swampy bush (*pa tham*) of *sakae* (*Combretum quadrangulare*), *huling* (*Sterculia alata*) and so on. Soils have heavy texture. Although rice production is not as unstable as that in type (A), farm mechanization is difficult and fertilizer application is not effective. Eight plots were identified as belonging to this type.

In 1994, water depth in each plot was measured every 10 days. The results are summarized by the types of land (Fig. 2). In this year, farmers reported that rainfall was less than normal along the Chi River, while it was as usual along the Mun River.

In the irrigated fields, water conditions were stable throughout the season. Ponding depth was 0 to 10 cm at the land preparation and planting stages in June and July, and was maintained at 5 to 20 cm during the growing period in August, September and

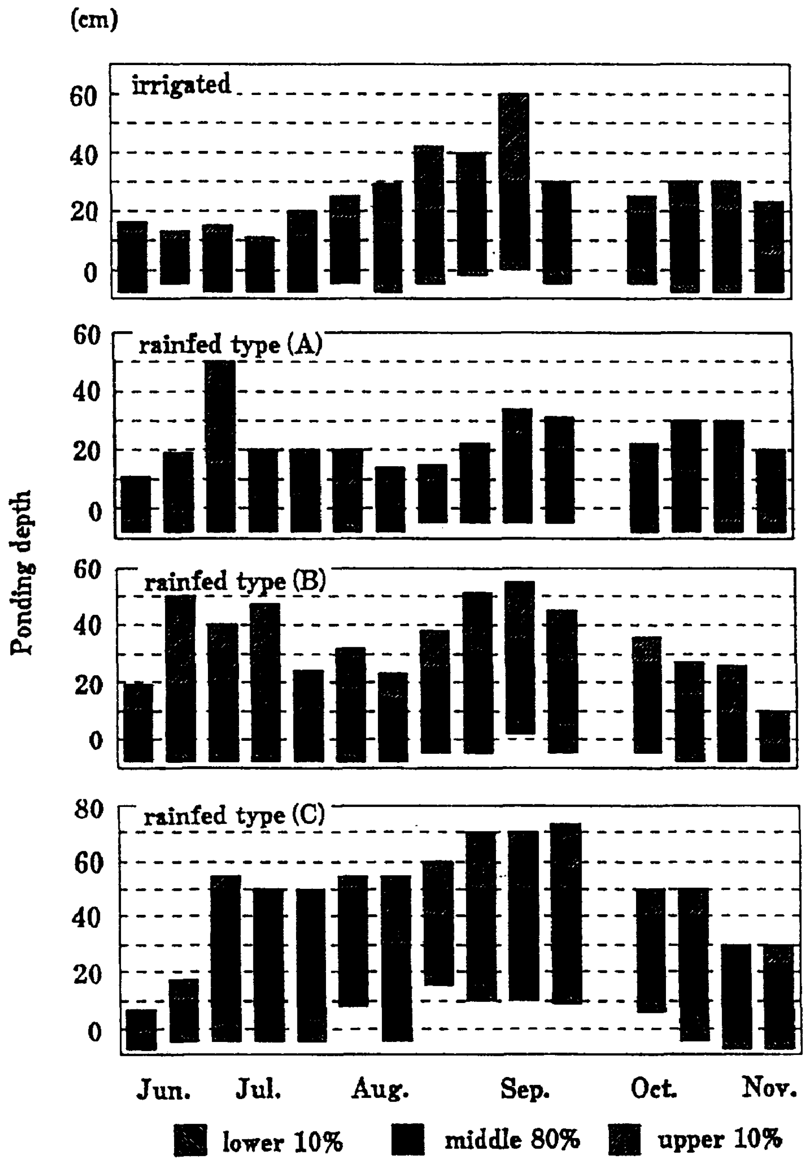

Fig. 2 Water Conditions of 1994 Rainy Season Cropping

Note: Unsaturated soil moisture conditions are converted into the equivalent negative ponding depths.

October. The water conditions in rainfed fields were strongly affected by the rainfall distribution. Type (A) had ponding water only in early July and during September and October. Type (C) was covered with deep water for four months from July to October, except in mid-August, when ponding water disappered in some plots. Type (B) showed similar water conditions to the irrigated fields, but with deeper ponding water in late June, early July and mid-September to prepare for the expected dry spell.

Water conditions naturally vary from one year to another according to the annual variation in rainfall, particularly in the case of rainfed paddy fields. However, the single year of observation in 1994 clearly demonstrated a sharp contrast between types (A), (B) and (C).

III Prevailing Rice Planting Technique

While transplanting was formerly the dominant method in the study area, it is now being replaced by two kinds of direct seeding, namely, dry seeding and wet seeding.

In the case of transplanting, the nursery is prepared and seeded in May or June. After this, the main field is first plowed following a substantial rainfall or irrigation. Then, preferably four to seven weeks after sowing, the paddy field is again plowed and puddled, and seedlings are transplanted [see Miyagawa *et al.* 1985 : 243-244]. In a field with sandy soil, puddling is omitted and seedlings are transplanted just after the second plowing, because the soil soon becomes compact, which makes transplanting difficult.

Dry seeding, called *phai khao* in Northeastern Thai dialect, encompasses a wide variety of practices. However, we noted three typical methods. The first is popular in rainfed type (C) fields with clay or clay loam soil. Ungerminated seed is first broadcast in a dry field in late April or early May. Then the field is plowed using a four-wheeled tiller, by which the seed is covered to enhance germination. This is done before the first substantial rain of the season.

The second method is popular in rainfed type (B) fields, particularly along M4 and M5 sections. Unlike the first method, the field is first plowed, ungerminated seed is broadcast, and then the field is plowed again. Again, this is performed before substantial rain comes.

The third method is popular in rainfed type (A) fields with sandy soil. As in the case of transplanting, the field is first plowed using a tiller or buffalo in May or June after enough rain comes, then farmers wait for two to three weeks until the soil attains the appropriate moisture content, which is less than saturated but moist enough for germination. Then the field is again plowed, ungerminated seed is broadcast, and the field is harrowed. When the monsoon rain comes late, farmers sometimes abandon transplanting due to lack of water in the middle of July, even though they have finished the first plowing. Then they adopt this method instead.

The sequence of operations in the three methods can be summarized as below.

1. Sowing and plowing before the first rain.
2. First plowing, sowing and second plowing before the first rain.
3. After the first rain, first plowing, second plowing, sowing and harrowing.

Wet seeding (*wan nam tom*) was first adopted for dry-season cultivation in irrigated areas, because it requires strict control of water conditions. Two weeks after the first plowing, the field is again plowed, harrowed and carefully leveled, and small ditches are dug at intervals of 5 to 8 m for better drainage. Then germinated seeds are broadcast on the field with 2 to 5 cm of ponding water, which helps seeds go deeper into the surface soil. The ponding water is drained the next day. The method of wet seeding is similar to that of nursery preparation for transplanting. Major differences are greater sowing density and the presence of ponding water at the time of broadcasting in the wet seeding method.

IV Changes in Planting Method

Table 1 summarizes the changes in planting method since 1988. In the late 1980s, most plots were transplanted, and none was wet seeded. Dry seeding was observed in less than 10% of the total plots, and only five farmers reported that they have practiced the method for a long time. Two of them cultivate rainfed type (A) plots and one rainfed type (B) plots in the southern part of M1 section, where rainfall is lowest in the study area. These three adopted dry seeding to eliminate water use for land preparation and transplanting. The other two farmers' plots are located near a stream along C5 and M3 sections and previously suffered from frequent floods, though they no longer do so thanks to improved drainage. They said that they broadcast rice seeds early enough that crop could withstand a flash flood. These accounts indicate that dry seeding was previously selected to cope with deficit or excess of water. The same explanation is given for preference of the dry seeding method in Eastern India and Myanmar [Fujisaka *et al.* 1993].

Planting method changed drastically in the first half of the 1990s. In 1995, transplanting accounts for around one half of the irrigated and rainfed type (C) plots, one

Table 1 Trends of Change in Planting Method

Year	Irrigated (IR)			Rainfed													
				Type (A)					Type (B)				Type (C)			
	TP	DS	WS	TP	DS	WS	NP	AB	TP	DS	WS	AB	TP	DS	WS	AB
1988	22	0	0	23	2	0	0	0	43	4	0	0	4	0	0	0
1989	22	0	0	23	2	0	0	0	44	3	0	0	4	0	0	0
1990	22	0	0	20	5	0	0	0	42	5	0	0	4	0	0	0
1991	22	0	0	20	4	1	0	0	42	5	0	0	4	0	0	0
1992	18	2	2	14	9	2	0	0	40	6	1	0	4	0	0	0
1993	15	5	2	6	17	2	0	0	30	15	2	0	2	2	0	0
1994	12	8	2	7	16	1	1	0	37	7	3	0	3	1	0	0
1995	12	8	2	6	14	2	0	3	37	5	4	1	2	0	1	1

Note: This table is based on interviews with 93 farmers on 98 plots. TP, DS, WS, NP and AB mean transplanted, dry seeded, wet seeded, not planted due to water deficit, and abandoned, respectively.

quarter of the rainfed type (A) plots, but three quarters of the rainfed type (B) plots. In place of transplanting, dry seeding is becoming popular, particularly in the irrigated and rainfed type (A) plots. Wet seeding is gradually increasing in the all types.

There was no change in planting method during the last five years in 8 irrigated (36%) and 36 rainfed plots (47%), including 3 plots where cultivation was abandoned. In the remainder, the change was not necessarily once-for-all (Table 2). The most common

Table 2 Patterns of Change in Planting Method

Planting Method					Number of Plots				
1991	1992	1993	1994	1995	IR	(A)	(B)	(C)	total
Unchanged									
WS	WS	WS	WS	WS	0	1	0	0	1
DS	DS	DS	DS	DS	0	1	2	0	3
TP	TP	TP	TP	TP	8	3	25	1	37
TP	TP	TP	TP	AB	0	1	1	1	3
Transplanting → dry seeding									
TP	DS	DS	DS	DS	1	3	2	0	6
TP	DS	DS	NP	DS	0	1	0	0	1
TP	TP	DS	DS	DS	2	5	0	0	7
TP	TP	DS	DS	AB	0	2	0	0	2
TP	TP	TP	DS	DS	2	1	0	0	3
TP	TP	TP	TP	DS	2	0	0	0	2
Alternation between transplanting and dry seeding									
DS	DS	DS	TP	DS	0	1	1	0	2
DS	DS	TP	TP	DS	0	1	0	0	1
TP	TP	DS	DS	TP	0	2	1	1	4
TP	TP	DS	TP	TP	1	0	7	0	8
TP	TP	TP	DS	TP	2	0	1	0	3
Others									
TP	TP	WS	WS	WS	0	0	1	0	1
TP	DS	DS	WS	WS	1	0	0	0	1
TP	DS	DS	DS	WS	0	1	0	0	1
TP	TP	DS	TP	WS	0	0	0	1	1
TP	TP	TP	TP	WS	1	0	3	0	4
DS	WS	WS	WS	TP	0	0	1	0	1
TP	WS	WS	WS	TP	1	0	0	0	1
TP	WS	WS	DS	DS	1	0	0	0	1
TP	WS	WS	TP	DS	0	1	0	0	1
TP	TP	DS	WS	TP	0	0	1	0	1
DS	DS	DS	DS	TP	0	1	1	0	2

Note: This table and Table 1 are based on the same data and use the same abbreviations.

pattern was a permanent change from transplanting to dry seeding: 7 irrigated and 14 rainfed plots. Alternating transplanting and dry seeding was observed in 3 irrigated and 15 rainfed plots. These two patterns account for three quarters of both irrigated and rainfed plots where the planting method changed. Wet seeding was adopted at least once in 4 irrigated and 9 rainfed plots, but it was discontinued in 2 irrigated and 3 rainfed plots after one to three years' cultivation. Surprisingly, no significant difference in the adoption of wet seeding can be found between irrigated and rainfed fields. This might suggest that the irrigation service in the study area was not fully functioning, unlike in the central part of the country, where wet seeding replaced transplanting not only in the dry season but also in the rainy season cultivation.

Table 2 also reflects farmers' trials to find the most suitable method or combination of methods of planting in an uncontrollable natural environment and under rapidly changing socio-economic conditions. Fig. 3 summarizes when farmers initiated such trial-and-error testing of planting method by introducing direct seeding. In all field types, on average, direct seeding was newly adopted at the start of the 1990s, and increased at the annual rate of 10 to 15% of plots for a few years. In the irrigated and rainfed type (B) plots, this trend continued after 1993, while in the rainfed type (A) and (C) plots, it hardly continued in 1994 and 1995. This difference indicates the instability of water conditions in type (A) and (C) plots, and its effect on the choice of planting method.

It is also noteworthy that abandoned paddy fields are emerging. Some of them are being converted to housing estates, and others are kept fallow, apparently awaiting similar development. In one case, an irrigated plot was converted to a fish pond. Since all

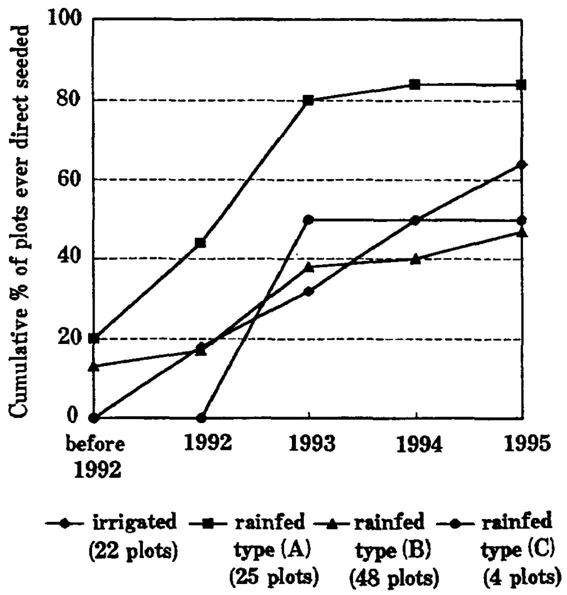

Fig. 3 Expansion of Direct Seeding Trials

the survey plots are located along motorable roads and are thus comparatively easily convertable to urban uses, they might not represent the whole area. Yet, this is a symptom of significant decrease in paddy area, a reversal of the trend of straight expansion for more than a century in the Northeast [Kono 1991].

V Farm Size and Family Labor

As mentioned above, labor shortage is a major reason why farmers adopt direct seeding. This is confirmed by comparison of farm size and family labor available for rice cultivation between those who have tried direct seeding, regardless of whether they continued, and those who have never tried it (Table 3).

Although the average farm size of the non-trial farmers is not significantly smaller than that of the trial farmers, nearly 90% of the farmers cultivating more than 40 *rai* (1 *rai* = 0.16 ha) have tried direct seeding, while about 70% of those with less than 40 *rai* have done so. Almost all trial farmers do not adopt direct seeding in all of their fields: some fields are reserved for transplanting to ensure production of the minimum requirement of rice. This is one reason why a higher proportion of farmers with larger farms than smaller have tried direct seeding.

Similarly, the average family labor force of the non-trial farmers is not significantly

Table 3 Numbers of Farmers Who Have Tried or Never Tried Direct Seeding, by Farm Size and Family Labor

	Never Tried	Tried
Farm size		
- 10 (*rai*)	8 (36%)	14 (64%)
11 - 20	9 (27%)	24 (73%)
21 - 30	2 (17%)	10 (83%)
31 - 40	4 (44%)	5 (56%)
More than 40	3 (19%)	13 (81%)
Average (*rai*)	19.0	25.7
Available family labor		
1 (person)	1 (13%)	7 (87%)
2	11 (26%)	32 (74%)
3	5 (22%)	13 (78%)
4	7 (42%)	12 (58%)
More than 4	2 (50%)	2 (50%)
Average	3.1	2.6

Note: This table is based on interviews with 92 farmers.

more than that of the trial farmers. However, all the farmers with one family labor, except for one farmer who cultivates only three *rai* of land, about three quarters of the farmers with two or three family members, and less than 60% of the farmers with four or more have tried direct seeding. This indicates a trade-off between continuing transplanting and adopting a labor-saving technique such as direct seeding to enable family members to take off-farm jobs.[1)]

VI Constraints to Adoption of the Planting Methods

Further examination of individual cases, particularly those who have never adopted direct seeding and those who adopted but subsequently discontinued it, should reveal the constraints to adoption of the planting methods.

Twenty percent of the farmers who have never adopted or have discontinued direct seeding reported that early flooding and poor drainage prevented them from adopting the method. Some of them experienced flooding just after broadcasting, which killed the young crop and required them to reseed or transplant later. Damage by excessive water depth can happen in any of the hydrological types since it is caused by localized showers and run-off from the surrounding higher land rather than river basin-wide flooding.

Weeds are another reason why farmers gave up direct seeding, particularly in irrigated and rainfed type (B) fields. Weeds such as *nuad pla duk* (*Fimbristylis miliacea (L.) Vahl*), *ya nok si chomphu* (*Echinochola colona (L.) Link*) and *kok samliam* (*Cyperus iria L.*) are common in fields where dry-seeded rice has been continuously cultivated for several years. These adversely affect rice yield. Some farmers alternated transplanting and dry seeding in order to control weeds. Others changed their planting method according to the rainfall of the early rainy season: transplanting when rainfall was high and dry seeding when it was low. This practice also results in control of weed growth.

Two farmers reported the outbreak of severe blast of densely broadcast rice, which made them go back to transplanting the following year. Two reported that some of their fields were close to the village, and chickens ate the drysown seed. Damage by wild birds was hardly reported, but it might become serious if dry seeding spreads.

Labor availability at the village level also affects the planting method. A farmer reported that since most of his neighbors had adopted dry seeding, he had to follow them because he could not find neighbors to help him transplant. A farmer in another village,

1) Nakada [1995: 541-543], based on an intensive village study in Yasothon during the early 1990s, found that temporary leave for off-farm work did not affect labor availability for rice cultivation, because workers returned home during the peak periods such as transplanting and harvesting. The difference between this and the present study might be partly due to intraregional difference in the Northeast: the study area, the Mun and Chi River basins, is most advanced while Yasothon is less so. It may also be partly due to the difference in time of observation, reflecting the rapidity of change.

on the other hand, reported that most farmers in his village continued transplanting, because they had enough help from seasonal workers from a village in a nearby province, where transplanting was finished earlier.[2)]

Labor availability at the family level is also related to the changes in the planting method. A farmer with two working family members and 14 *rai* of land continued transplanting, because every year her relatives came from a nearby province to help with the work. Another aged farmer living with his wife and cultivating 35 *rai* of land discontinued transplanting and adopted dry seeding in 1994, because his wife had to take care temporarily of their grandchild, whose parents needed some time to settle down in a new place. They resumed transplanting in 1995, because their son came to pick his child up before the season.

The status of landholding also affects the planting method. A share-cropping tenant who cultivates an irrigated field reported that the landowner did not allow him to adopt wet seeding, because he was afraid that his share would be reduced. Other tenants also reported the same constraint in 1994, but they adopted dry seeding for the 1995 crop. It is not known whether their contract conditions changed.

The individual cases examined above are summarized in Table 4. It indicates that the direct seeding method in Northeast Thailand is presently in the process of evolution, and farmers are experimenting with it.

About half of the non-trial farmers, who are mostly smallscale cultivators and seldom sell rice, pointed to a lower yield and a consequent shortage of rice for home

Table 4 Problems Involved in Direct Seeding and Farmers' Countermeasures

Problem	Cause	Countermeasure
unreliable production	techniques under test	trial adoption in part of one's holding
weeds	no puddling	alternate direct seeding and transplanting
chicken attack	no soil cover just after sowing	avoid fields close to village
submergence of young crop	poor drainage	broadcast earlier, replant if crop is damaged
disease	high crop density	reduce crop density
disagreement of landowner	worry of lower revenue	negotiation

2) After finishing their own transplanting, one or two villagers come scouting for transplanting work. If there is any, the scouts start working. If they do not return home within two to three days, 20 to 30 of their fellow villagers follow them. Although there is no formal contract between the two villages, the inter-village labor migration is well established.

consumption as their primary reason for not adopting the dry seeding method. A considerable number of the farmers who adopted but discontinued the method also reported getting lower yields than with the transplanting method. A cutting survey carried out in 45 transplanted and 22 dry seeded plots in 1994/95 cropping shows significantly lower yield in the latter (2.3 t/ha) than the former (3.0 t/ha). In contrast, however, a few farmers reported that the yield of not only wet-seeded but also dry-seeded rice was higher than that of transplanted. It is thus not clear whether the spread of direct seeding would result in a decrease in rice yield or not. But it could be said that farmers tended to attach greater importance to minimizing labor input than maximizing rice production. This indicates the possibility of technological innovation, not necessarily for greater land productivity but for greater labor productivity.

It is also noteworthy that two farmers mentioned that they had not adopted dry seeding because they were hard workers. They seemed to be proud of themselves. One, aged around 35, cultivates 11 *rai* of irrigated land with his wife, and the other, aged around 40, cultivates 32 *rai* of rainfed land with his wife. In that a considerable number of farmers also continue transplanting, under similar hydrological and labor conditions, it is questionable whether they actually are hard workers. But it is likely that transplanting will be a symbol of diligence.

VII Conclusions

The planting method of lowland rice in Northeast Thailand is now changing, primarily as a result of labor shortage. But the adoption of new methods is also governed by the given hydrological conditions of paddy lands.

Until the 1980s, dry seeding was observed only in fields very vulnerable to drought or flood, and most fields were transplanted. However, during the early 1990s, the accelerated economic growth attracted Northeastern Thai farmers to Bangkok and its suburbs, and this required labor-saving techniques to be adopted for rice cultivation in their home villages. Direct seeding is typical of the chosen techniques, which first spread to rainfed type (A) fields, the most vulnerable to drought, and later to all hydrological types of fields. Dry seeding was the most common form, but wet seeding was also adopted in irrigated fields, and rainfed fields having access to a temporary water body.

Another emerging choice, though still far from popular, is to abandon rice cultivation and to sell the land, to build a small-sized enterprise such as a gas station, or just to keep the land fallow. The change of landuse from rice cultivation to a more profitable venture such as fruit and vegetable cultivation could not be observed in this study, except in one case of setting up aquaculture.

The more direct urban-rural relationship in terms of people's mobility and the circulation of information and money has motivated Northeastern Thai farmers to rely more on the market economy, or money-based economy, and to attach less importance to the rice-based economy, which had strongly constrained the farmers until a decade ago [Fukui 1993 : 316-317]. Self-sufficiency in rice is no longer a significant determinant of farmers' decision-making on landuse and cultivation methods.

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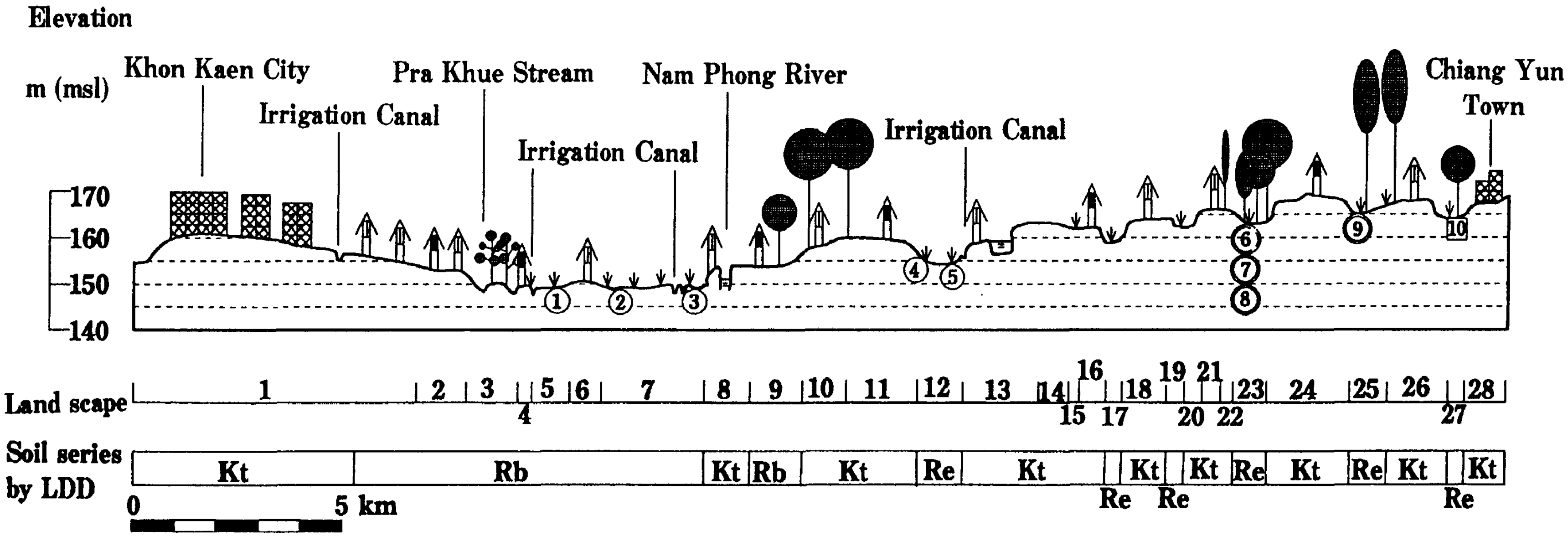
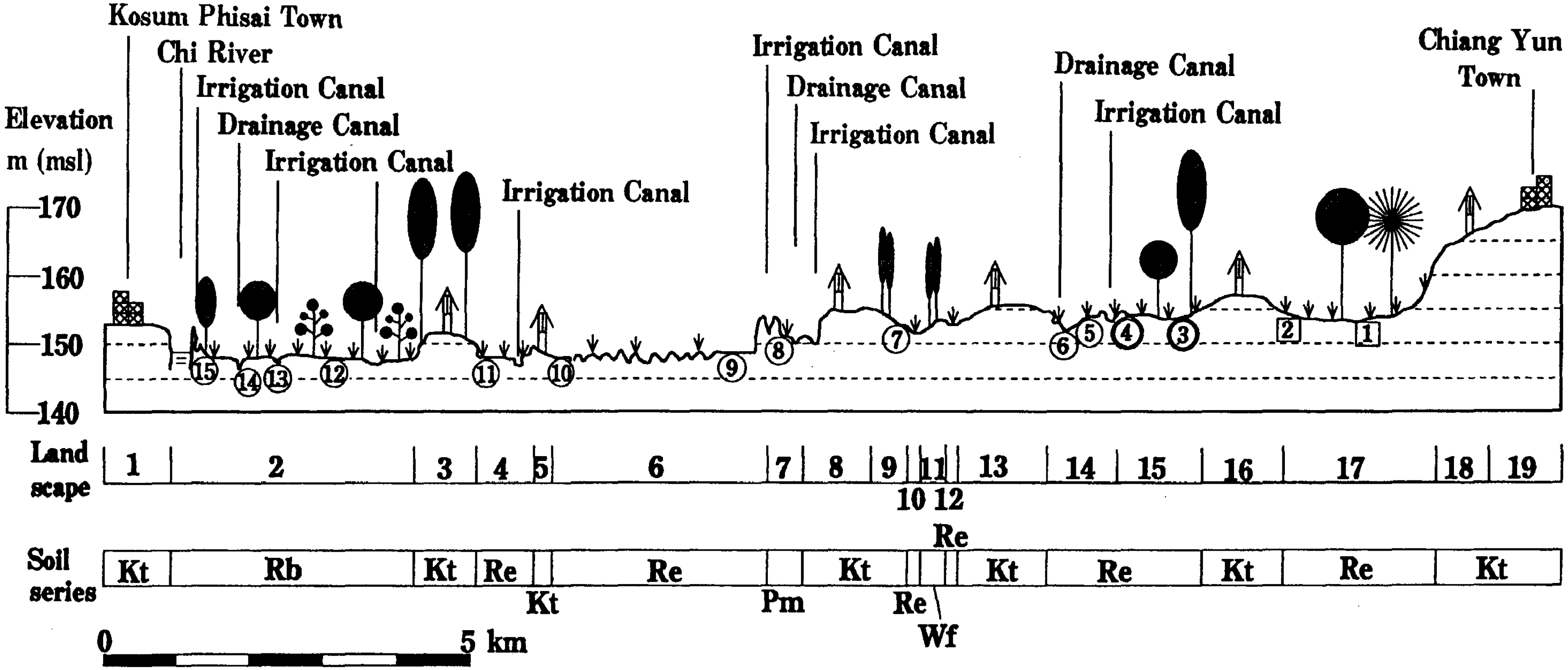


1. Khon Kaen city; 2. Aeo Mong village, outskirts of Khon Kaen city with three rice mills; 3. Phra Khue stream and *pa tham* or swampy bushland; 4. Factories and construction material shops; 5. Consolidated fields irrigated by the Nam Pong-Nong Wai project (NNP); 6. Don Du village; 7. Irrigated paddy field, vegetable and flower gardens and fish ponds; 8. Tha Hin village; 9. Brick factories, a gasoline station, shops and orchards; 10. Ku Thong village covered with trees such as *chamchuri* (*Samanea saman*) and *makham thet* (*Pithecellobium dulce*); 11. Brick factories and uncultivated upland fields; 12. Irrigated paddy fields of NNP; 13. Kham Pia village with a large natural pond; 14. Uncultivated upland fields; 15. Uncultivated paddy fields; 16. A cassava factory; 17. Paddy fields; 18. Kheng village; 19. Uncultivated paddy fields; 20. Uncultivated upland fields; 21. Nong Sa Phang village; 22. Eucalyptus plantation; 23. Partly saline paddy fields with termite mounds on which big trees such as *khoi* (*Streblus asper*), *sadao* or nim (*Azadirachta indica*), *tako* (*Diospyros rhodocalyx Kurz*) and *chamchuri* stand; 24. Animal feed research station and a high school; 25. Paddy fields with 2 to 5 trees per *rai* of *yang* (*Dipterocarpus alatus*) and *sabaeng* (*Dipterocarpus intricatus*); 26. Sang Kaeo village; 27. Paddy fields with termite mounds on which trees such as *khoi* and *tako* stand; 28. Chiang Yun town.

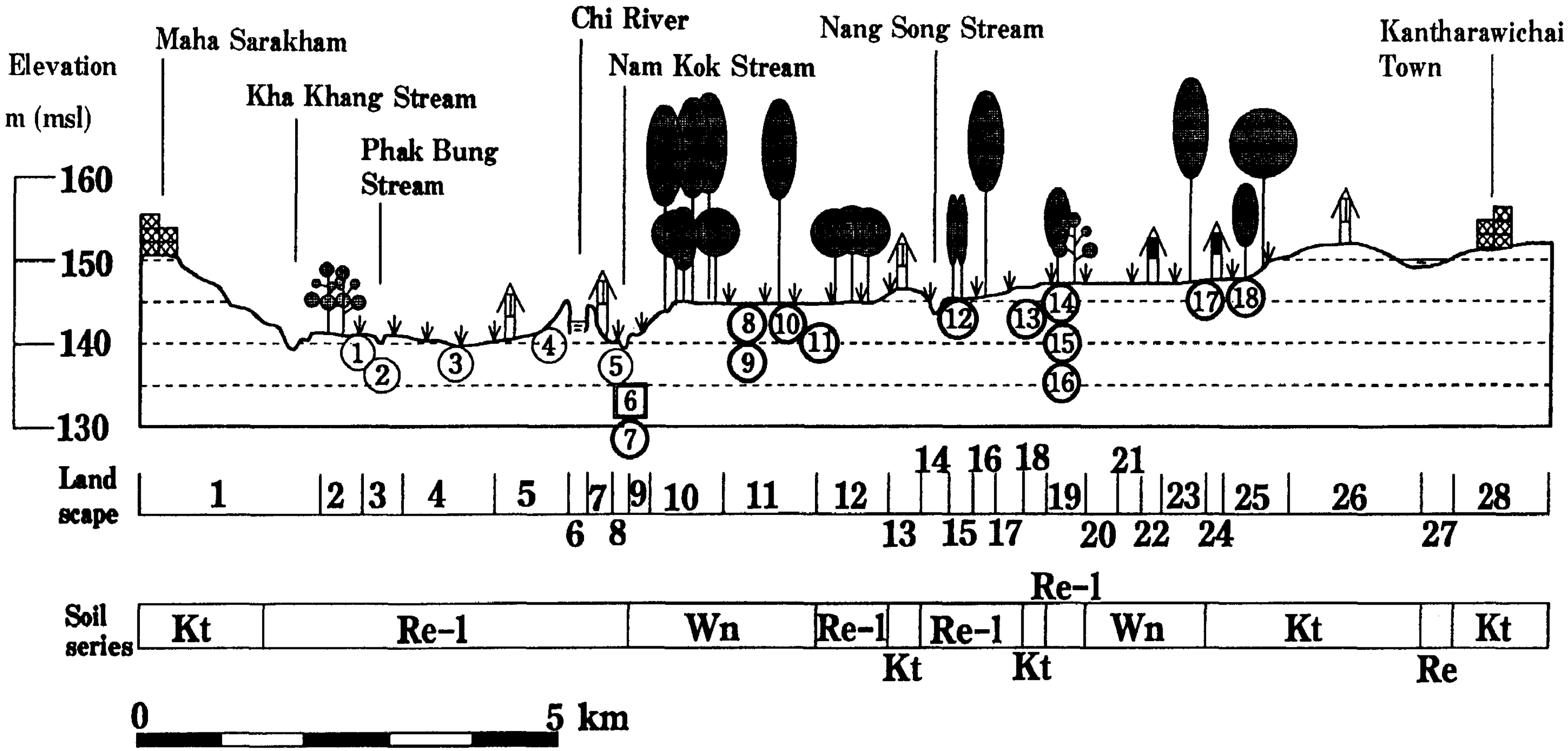
Appendix 1 Khon Kaen — Chiang Yun (C1) Cross Section

Note: Plot number with ○, ◎, □ and ▣ in Appendices 1 to 10 means irrigated, rainfed type (A), (B) and (C), respectively.



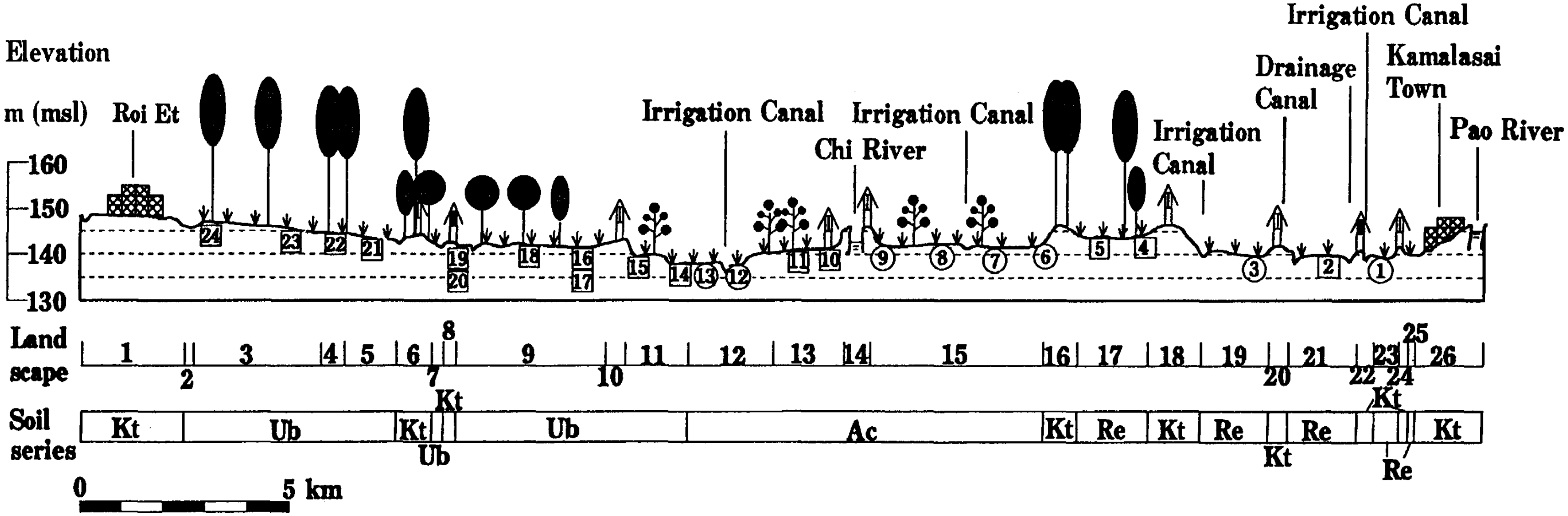
1. Kosum Phisai town; 2. Irrigated paddy fields of NNP with 1 or 2 individuals per *rai* of trees such as *khae pa* (*Dolichandrone spathacea*), *sakae* (*Combretum quadrangulare*), *kra thum* (*Mitragyna microphylla*), *tako*, and *sadao*; 3. Yang Yai village with *yang* trees 20 meters high; 4. Irrigated paddy fields of NNP with rank weeds of *kok samliam* (*Cyperus digitatus*); 5. Yang Noi village; 6. Fish seed ponds; 7. Irrigated paddy fields of NNP; 8. Phak Nok village; 9. Eucalyptus plantation; 10. Irrigated paddy fields of NNP with rank weeds of *ya nok si chomphu* (*Echinochloa colona(L.) Link*); 11. Eucalyptus plantation; 12. Irrigated paddy fields of NNP; 13. Khuan village; 14. Partly saline irrigated paddy fields of NNP with rank weeds of *ya nok si chomphu*; 15. Paddy fields with termite mounds and 1 to 2 trees per *rai* of *tako*, *khae pa* and *bok* (*Irvingia malayana*) and others; 16. Khi village; 17. Paddy fields with *chamchuri* and sugar plam around huts; 18. Khok Sung village; 19. Chiang Yun town.

Appendix 2 Kosum Phisai − Chiang Yun (C2) Cross Section



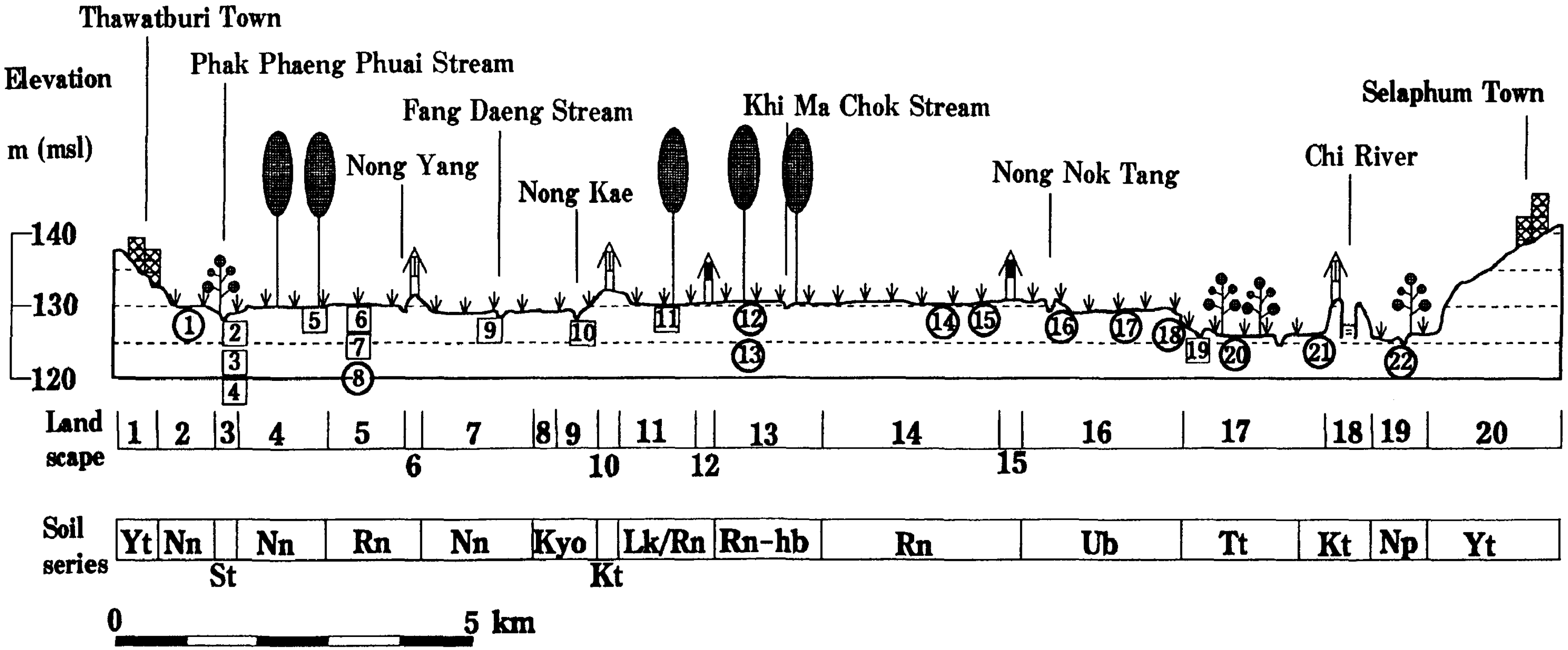
1. Maha Sarakham city; 2. *Pa tham* with *sakae* and *kra thum*; 3. Pump-irrigated paddy fields and flower gardens; 4. Partly irrigated paddy fields; 5. Tha Dindam village; 6. Chi River; 7. Tha Khon Yang village; 8. Partly pump-irrigated fields; 9. Paddy fields; 10. Forest temple; 11. Paddy fields with around 5 individuals per *rai* of trees such as *teng* (*Shorea obtusa*), *rang* (*Shorea siamensis*), *bok* and *sabaeng*; 12. Paddy fields, fish ponds and fruit gardens; 13. Hua Khua village; 14. Paddy fields; 15. Eucalyptus plantation; 16. Paddy fields with a few *sabaeng* trees; 17. Paddy fields with termite mounds; 18. Bush land; 19. Paddy fields with one tree per *rai* of *sadao* or *sakae*; 20. Bush land; 21. Paddy fields; 22. Primary school; 23. Paddy fields with a few *sabaeng* trees; 24. Primary school; 25. Paddy fields with a few *phutsa* (*Zizyphus jujuba*) and *sadao* trees; 26. Moated village of Khan Tha; 27. Natural pond; 28. Kantharawichai town.

Appendix 3 Maha Sarakham — Kantharawichai (C3) Cross Section



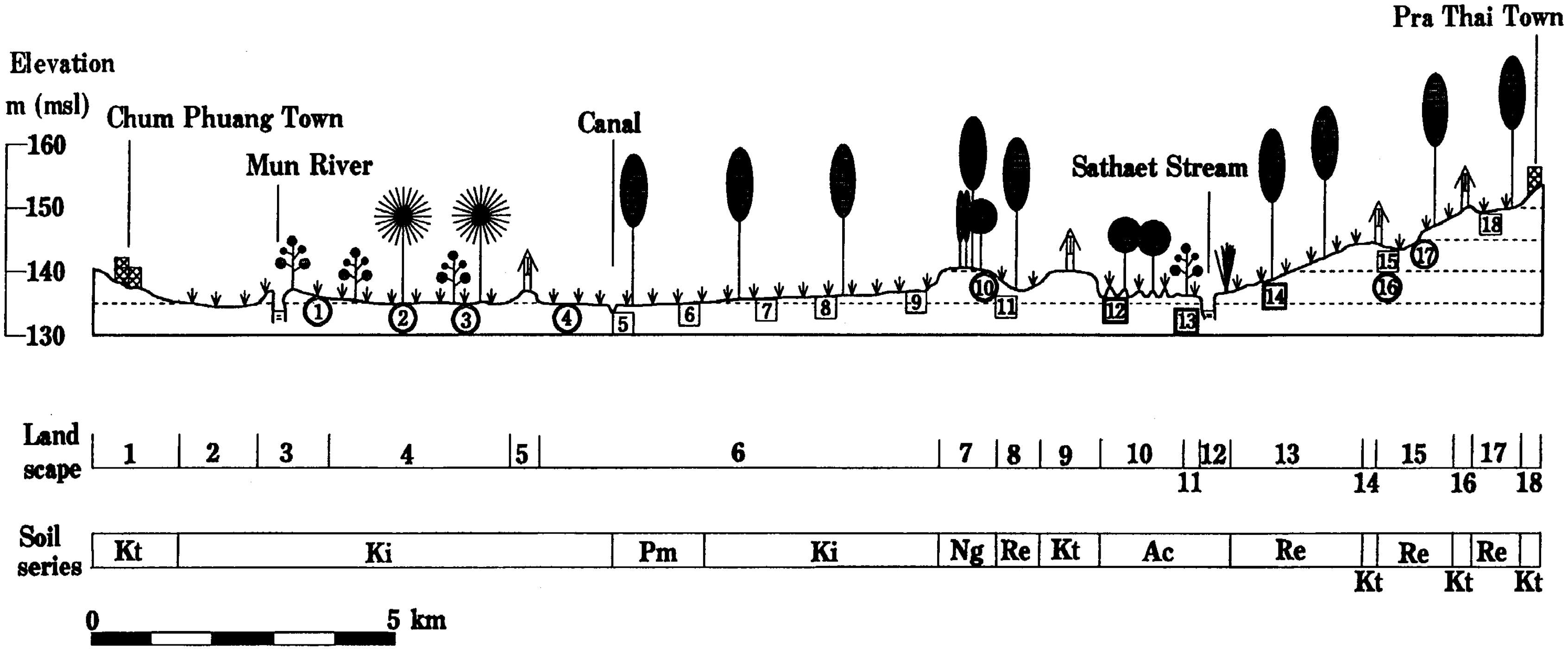
1. Roi Et city; 2. Uncultivated fields covered with *ya khon* (*Brachiaria mutica*); 3. Garbage dump and paddy fields with 1 to 3 trees per *rai* of *yang* and *sabaeng*; 4. Paddy fields with 5 to 10 individuals per *rai* of *yang* trees 20 meters high; 5. Paddy fields; 6. Lao Kluai village with a sacred forest; 7. Paddy fields; 8. Police box and shops; 9. Paddy fields with termite mounds on which trees such as *sadao*, *tako* and tamarind stand; 10. Nong Kheng village; 11. Paddy fields with *sakae* trees on levees; 12. Partly pump-irrigated fields; 13. Non Sawan village, brick factories, partly irrigated fields and *pa tham*; 14. Chi River and Tha Luang village; 15. Irrigated fields of the Lam Pao project (LPP) with 1 to 3 trees per *rai* of *kra thum* and *sakae*; 16. Forest with tall *yang* trees; 17. Paddy fields with a few tall trees of *yang*, *sadao* and *bok*; 18. Bo village; 19. Irrigated paddy fields of LPP; 20. Lao village; 21. Partly irrigated paddy fields of LPP; 22. Rice mill; 23. Irrigated paddy fields of LPP; 24. Sra Bua village; 25. Irrigated fields of LPP; 26. Kamalasai town.

Appendix 4 Roi Et — Kamalasai (C4) Cross Section



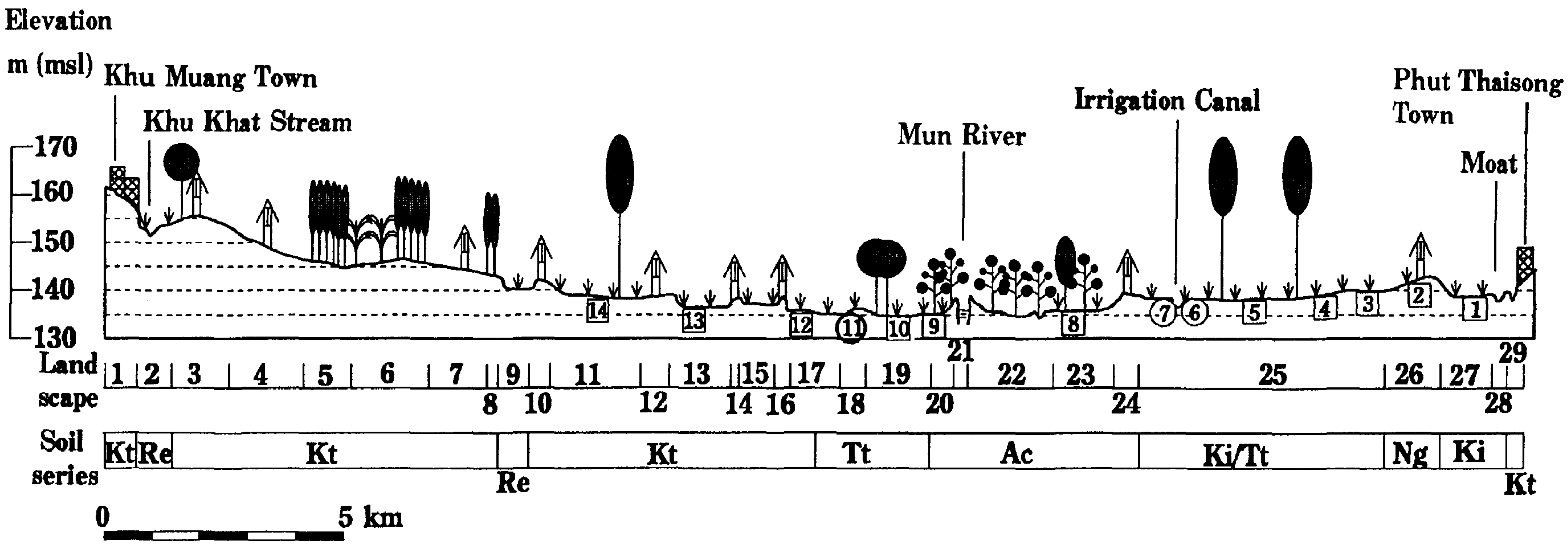
1. Thawatburi town; 2. Partly uncultivated paddy fields; 3. Paddy fields with 2 to 3 trees per *rai* of *kra thum*; 4. Paddy fields with 2 to 5 *sabaeng* trees per *rai*; 5. Paddy fields with few trees; 6. Um Mao village; 7. Paddy field; 8. Bush land with saline soil; 9. Paddy fields; 10. Bo village (salt manufacture); 11. Paddy fields with 2 to 3 *sabaeng* trees per *rai*; 12. Primary school; 13. Paddy fields with 3 to 5 *sabaeng* trees per *rai*; 14. Partly uncultivated paddy fields; 15. Pig farm; 16. Paddy fields; 17. Paddy fields with 2 to 3 trees per *rai* of *kra thum* and *sakae*; 18. Chi River and Tha Sabaeng village; 19. Paddy fields with a few *kra thum* trees; 20. Selaphum town.

Appendix 5 Thawatburi — Selaphum (C5) Cross Section



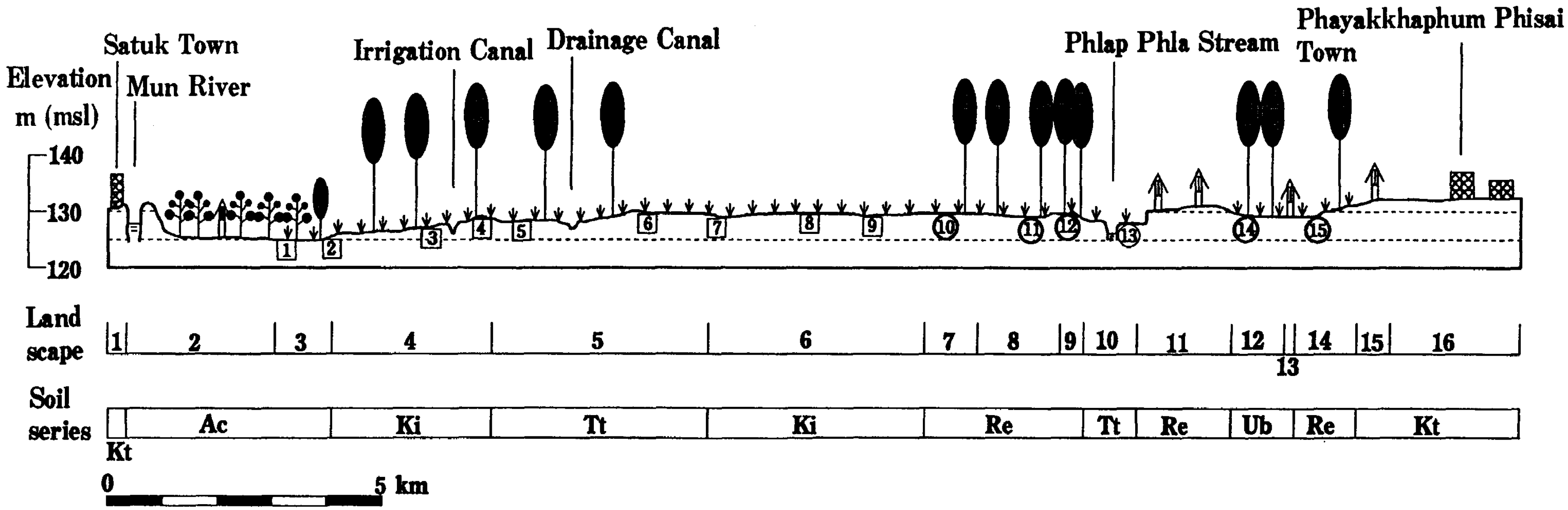
1. Chum Phuang town; 2. Pump-irrigated paddy fields; 3. Mun River, *pa tham* and paddy fields; 4. Paddy fields with a few trees of *kra thum* and sugar plam; 5. Khun Lakhon village; 6. Partly pump-irrigated paddy fields with few *sabaeng* trees; 7. Eucalyptus plantation and natural woodland; 8. Paddy fields with 1 to 3 *sabaeng* trees per *rai*; 9. Don Man village; 10. Integrated farms of rice, fruit and vegetables with fish, ducks and pigs; 11. Paddy fields and *pa tham*; 12. Sathaet stream and bamboo bush; 13. Paddy fields with a few *sabaeng* trees and termite mounds; 14. Si Chomchun village; 15. Paddy fields with a few *sabaeng* trees; 16. Moated village of Khi Lek; 17. Paddy fields with 1 or 2 *sabaeng* trees per *rai*; 18. Pra Thai town.

Appendix 6 Chum Phuang — Pra Thai (M1) Cross Section



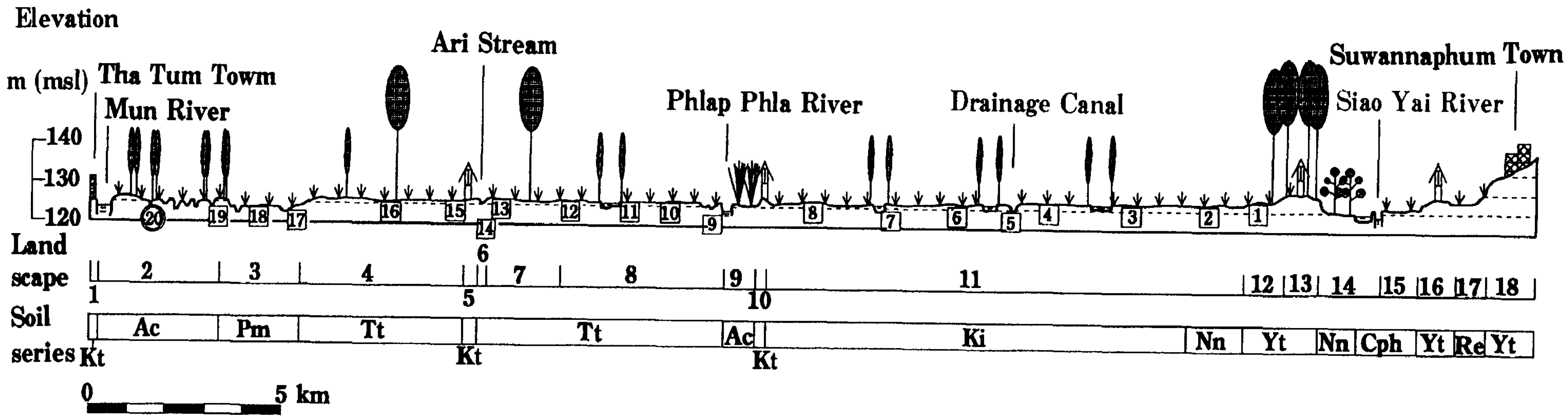
1. Khu Muang town; 2. Paddy fields with termite mounds; 3. Khok Saat village; 4. Nong Wa village; 5. Eucalyptus plantation; 6. Sugarcane fields and *krathin narong* (*Acacia auriculae-formis*) reforestation area; 7. Dong Kheng village; 8. Eucalyptus plantation; 9. Paddy fields with termite mounds; 10. Thang Phat village; 11. Paddy fields with termite mounds and a few *sabaeng* trees; 12. Moated village of Phae; 13. Paddy fields; 14. Non Sung village; 15. Paddy fields with few trees; 16. Bao Noi village; 17. Paddy fields with few trees; 18. Salt mound partly occupied by paddy fields; 19. Mango garden and paddy fields; 20. *Pa tham* and paddy fields; 21. Mun River; 22. *Pa tham* of *sakae* and *huling* (*Sterculia alata*); 23. Paddy fields with a few trees of *kra thum* and *chan* (*Butea monosperma*); 24. Bung Boa village; 25. Paddy fields with a few *sabaeng* trees; 26. Chan village; 27. Paddy fields; 28. Double moats surrounding Phut Thaisong town; 29. Phut Thaisong town.

Appendix 7 Khu Muang — Phut Thaisong (M2) Cross Section



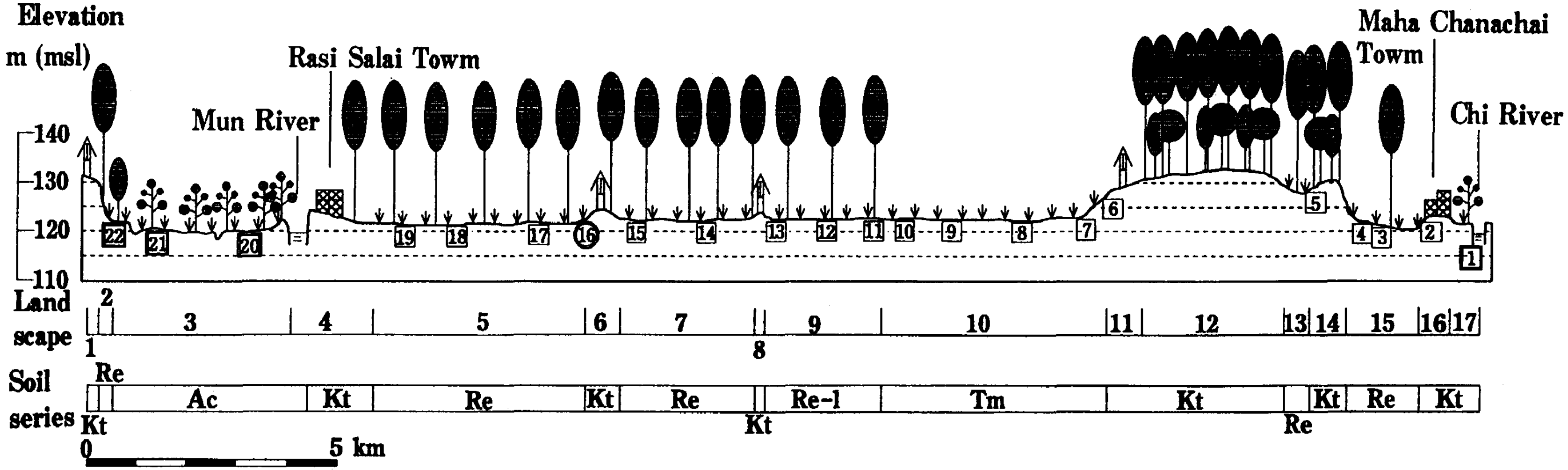
1. Satuk town; 2. *Pa tham*, sand pits and gasoline stations; 3. Paddy fields with a few trees of *kra thum*, *sakae* and *chan*; 4. Paddy fields with 2 to 5 *sabaeng* trees per *rai*; 5. Paddy fields with few trees; 6. Paddy fields; 7. Paddy fields with around 1 *sabaeng* tree per *rai*; 8. Paddy fields with 2 to 5 trees per *rai* of *sabaeng* and *saat* (*Dipterocarpus obtusifolius*); 9. Paddy fields with 5 to 10 trees per *rai* of *sabaeng*, *saat* and *yang*; 10. Phlap Phla stream; 11. Buran village and Muang Sua moated village; 12. Paddy fields with 5 to 10 trees per *rai* of *sabaeng*, *teng* and *rang*; 13. Nong Kok village; 14. Partly saline paddy fields with few *sabaeng* trees; 15. Nong Khaen village; 16. Phayakkhaphum Phisai town.

Appendix 8 Satuk — Phayakkhaphum Phisai (M8) Cross Section



1. Tha Tum town; 2. Sand pits, eucalyptus plantations and paddy fields; 3. Paddy fields; 4. Paddy fields with few trees of *krathin narong* and *sabaeng*; 5. Huai Ari village; 6. Ari stream; 7. Paddy fields with few trees of *sabaeng, teng* and *rang*; 8. Paddy fields and a few fish ponds encircled by planted trees of eucalyptus and *krathin narong*; 9. Phlap Phla stream along with *patham* (wild bamboo); 10. Sarai village; 11. Paddy fields and a few fish ponds encircled by planted trees of eucalyptus and *krathin narong*; 12. Paddy fields with 1 to 2 *sabaeng* trees per *rai*; 13. Ku village and old pagoda; 14. Siao Yai stream, *pa tham* and fish ponds; 15. Paddy fields; 16. Sanam village; 17. Paddy fields; 18. Suwannaphum town.

Appendix 9 Tha Tum — Suwannaphum (M9) Cross Section



1. Nong Ung village; 2. Paddy fields with various 2 to 5 individuals per *rai* of trees such as *sadao, tabaek, (Lagerstroemia calyoulata) teng* and *rang*; 3. Paddy fields and *pa tham*; 4. Mun River and Rasi Salai town; 5. Paddy fields with 5 to 10 trees per *rai* of *sabaeng* and *saat*; 6. Du village; 7. Paddy fields with 5 to 10 trees per *rai* of *sabaeng* and *saat*; 8. Khi Nok village; 9. Paddy fields with 3 to 5 trees per *rai* of *sabaeng* and *saat*; 10. Paddy fields; 11. Phonlawai village; 12. Forest of *yang, teng, rang* and bush; 13. Paddy fields with 2 to 3 trees per *rai* of *sabaeng* and *saat*; 14. Scout camp with trees of *yang, teng, rang, saat* and bush; 15. Paddy fields with a few trees of *sabaeng* and *saat*; 16. Maha Chanachai town; 17. Chi River, *sakae* dominating *pa tham* and paddy fields.

Appendix 10 Rasi Salai — Maha Chanachai (M5) Cross Section